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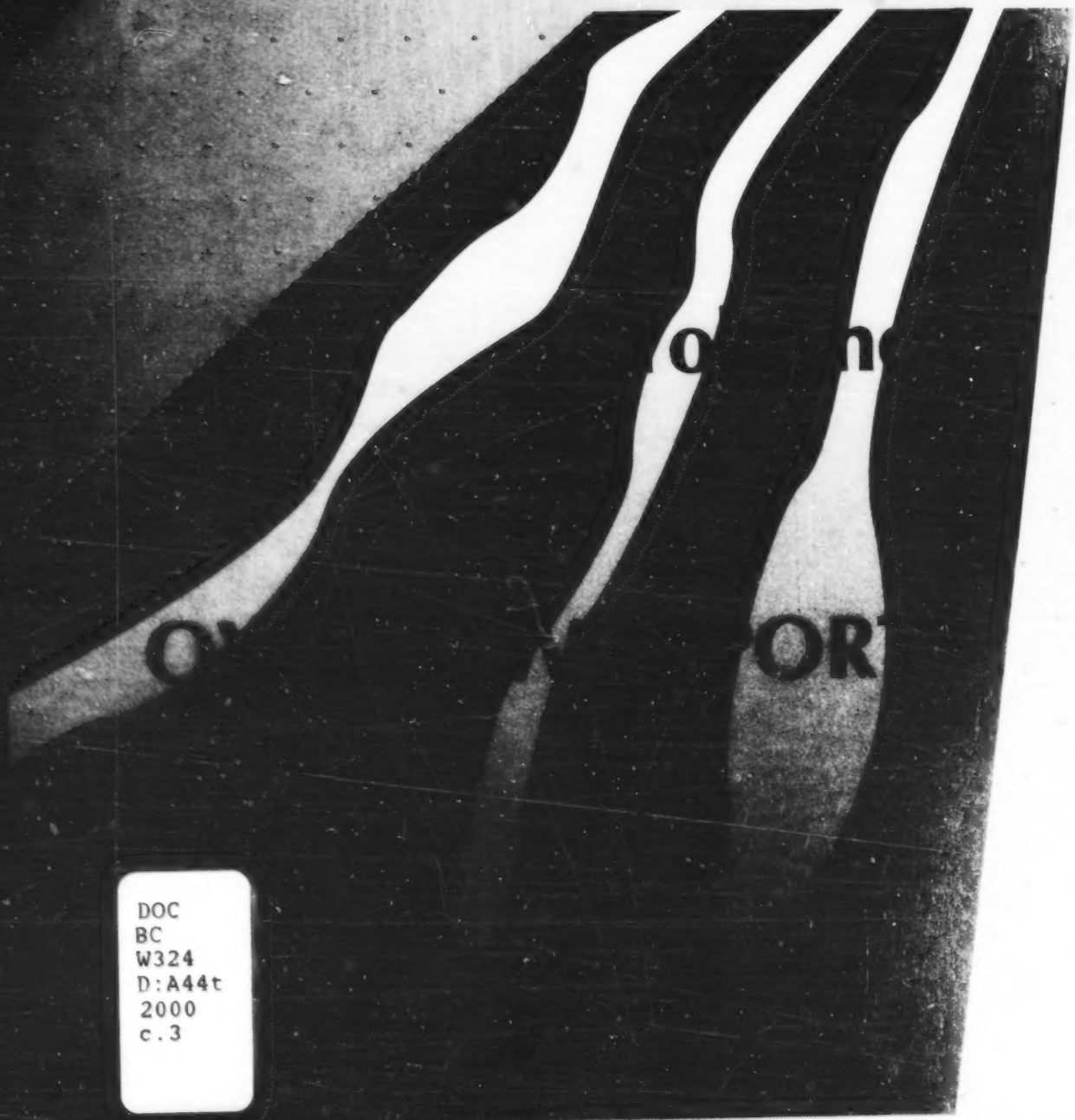
OVERVIEW - TOLUENE

Water Quality

GUIDELINES



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WATER MANAGEMENT BRANCH
ENVIRONMENT AND RESOURCE MANAGEMENT DIVISION
MINISTRY OF ENVIRONMENT, LANDS AND PARKS

AMBIENT WATER QUALITY GUIDELINES FOR TOLUENE

OVERVIEW

Prepared pursuant to Section 2(e) of the
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SUMMARY

THIS DOCUMENT is one in a series that establishes ambient water quality guidelines for British Columbia. It is based on a technical report prepared for the Canadian Council of Ministers of Environment (CCME) proposing Water Quality Guidelines for Toluene (July 1995 update). This overview report assesses those guidelines for use in British Columbia, assesses more recent information and makes amendments where appropriate to suit BC conditions. The guidelines are safe conditions or levels that have province-wide application and are set to protect various water uses. This report sets guidelines for toluene to protect drinking water, freshwater and marine aquatic life and livestock watering. Based on this evaluation, the CCME guidelines adopted by the province were for drinking water and livestock watering, while adjustments were deemed necessary to protect aquatic life (fresh and marine waters).

A major use of the guidelines is to set ambient water quality objectives. The objectives are the guidelines modified or adopted to protect the most sensitive designated water use in a particular body of water. The objectives are used in the preparation of waste management plans, pollution prevention plans, waste management permits, orders, or approvals. The latter three are the only documents that have legal status. The guidelines are also used as a basis in evaluating contaminated sites and determining remediation requirements.

The guidelines are summarized in the Table below.

TABLE 1: SUMMARY OF WATER QUALITY GUIDELINES FOR TOLUENE

Characteristic / Water Use	Maximum Total Toluene mg/L
Drinking Water (aesthetic objective)	0.024
Recreation	None proposed
Freshwater Aquatic Life	0.039
Marine and Estuarine Aquatic Life	0.33
Crop Irrigation	None proposed
Livestock Watering	0.024

PREFACE

THE MINISTRY OF ENVIRONMENT, LANDS AND PARKS develops province-wide ambient water quality guidelines for variables that are important in the surface waters of British Columbia. This work has the following goals:

1. to provide guidelines for the evaluation of data on water, sediment, and biota;
2. to provide guidelines for the establishment of site-specific ambient water quality objectives.

Ambient water quality objectives for specific waterbodies will be based on the guidelines and also consider present and future uses, waste discharges, hydrology/limnology/oceanography, and existing background water quality. The process for establishing water quality objectives is more fully outlined in *Principles for Preparing Water Quality Objectives in British Columbia,* copies of which are available from Water Quality Section of the Water Management Branch.

Neither guidelines nor objectives that are derived from them have any legal standing. The objectives, however, can be used to calculate allowable limits or levels for contaminants in waste discharges. These limits are set out in waste management permits and thus have legal standing. The objectives are not usually incorporated as conditions of the permit. The guidelines are used as a a starting point for evaluating possible remediation requirements for contaminated sites.

The definition adopted for a guideline is: "A maximum and/or a minimum value for a physical, chemical or biological characteristic of water, sediment or biota, which should not be exceeded to prevent specified detrimental effects from occurring to a water use, including aquatic life, under specified environmental conditions."

The guidelines are province-wide in application, are use-specific for some or all of the following water uses:

- Raw drinking, public water supply and food processing[1]
- Aquatic life and wildlife

[1] The guidelines apply to the ambient raw water source before it is diverted or treated for domestic use. The Ministry of Health regulates the quality of water for domestic use after it is treated and delivered by a water purveyor.

- Agriculture (livestock watering and irrigation)
- Recreation and aesthetics[1]
- Industrial (water supplies)

The guidelines are set after considering the scientific literature, guidelines from other jurisdictions and general conditions in British Columbia. The scientific literature gives information on the effects of toxicants on various life forms. This information is not always conclusive because it is usually based on laboratory work, which, at best, only approximates actual field conditions. To compensate for this uncertainty, guidelines have built-in safety factors that are conservative but reflect natural background conditions in the province.

The site-specific water quality objectives are, in most cases, the same as guidelines. However, in some cases, such as when natural background levels exceed the guidelines, the objectives could be less stringent than the guidelines. In relatively rare instances, for example if the resource is unusually valuable or of special provincial significance, the safety factor could be increased by using objectives which are more stringent than the guidelines. Another approach in such special cases is to develop site-specific guidelines by carrying out toxicity experiments in the field. This approach is costly and time-consuming and therefore seldom used.

Guidelines are subject to review and revision as new information becomes available.

[1] Guidelines relating to public health at bathing beaches are the same as those used by the Ministry of Health which regulates the recreation and aesthetic use.

INTRODUCTION

TOLUENE is a colourless liquid at room temperature with a gasoline-like aroma. It occurs naturally in coal and crude oil and is found in consumer products such as paints, cosmetics, upholstery, carpet cleaners, cigarette smoke, pesticides and gasoline. In Canada, toluene is used in the production of benzene and as an octane enhancer instead of lead in gasoline refining.

Toluene can enter aquatic environments during production, usage, storage, transportation and spills. Toluene has been detected throughout North America in effluents from municipalities, industries, industrialized river basins, groundwater, sediments, soil and water. It is released into the air from burning oil, gas and coal. Physical, biological and chemical processes remove toluene from all media so there is little tendency for it to accumulate in environmental compartments. Toluene can be removed from water by volatilization and biodegradation, but does not tend to hydrolyze or adsorb to sediments. It may leach into groundwater if released to land. Toluene is volatile with a half-life of up to two weeks in water. The log octanol-water partition coefficient (K_{ow}) is 2.7.

The CCME noted that the following toxicity tests (lowest value shown) from the literature were deemed as primary:

Species	Exposure Duration	Age/ Size	Response	Toxicity (mg/L)	Reference
Rainbow trout (*Oncorhynchus mykiss*)	Chronic	Hatch	**27d LC_{50}**	**0.020**	Black et al, 1982
	Chronic	4d posthatch	**23d LC_{50}**	**0.030**	Black et al, 1982
	Acute	--	96h LC_{50}	5.8	Galassi et al, 1988
Leopard frog (*Rana pipiens*)	Chronic	4d posthatch	**9d LC_{50}**	**0.39**	Black et al, 1982
	Chronic	Fert to hatch	**5d LC_{50}**	**0.51**	
Salamander (*Ambystoma gracile*)	Chronic	4d posthatch	9.5d LC_{50}	0.85	Black et al, 1982
	Chronic	Fert to hatch	5.5d LC_{50}	1.1	
Coho salmon (*Oncorhyncus kisutch*)	Chronic	Fry	40d EC	2.8-5.0	Moles, 1981
	Acute	0.3g	96h LC50	5.46	
Water flea (*Daphnia magna*)	Acute	24h	24h EC50 (immobile)	7.0	Galassi et al, 1988
Goldfish (*Carassius auratus*)	Chronic	1-1.5yrs	30d LC_{50}	14.6	Brenniman et al, 1976
	Acute	1-1.5yrs	96h LC_{50}	22.8	
	Acute	13-20cm	72h LC_{50}	25.3	
	Acute	20-80g	48h LC_{50}	27.6	

Species	Exposure Duration	Age/ Size	Response	Toxicity (mg/L)	Reference
Guppy *(Lebistes reticulatus)*	Acute	--	96h LC_{50}	28.2	Galassi et al, 1988
Fathead minnow *(Pimephales promelas)*	Chronic	30-35d	8d LC_{50}	44.1	Hall et al, 1984, 1989
	Acute	30d	96h LC_{50}	18-31	Devlin et al, 1982
	Acute	Protolarvae	96h LC_{50}	25-36	Devlin et al, 1982
	Acute	Embryo	96h LC_{50}	55-72	Devlin et al, 1982

The most sensitive freshwater species to toluene was rainbow trout (*Oncorhynchus mykiss)* with a 27-d LC_{50} of 0.020 mg/L. Coho salmon (*Oncorhynchus kisutch)* exhibited a weight loss after 40-d exposure to 2.8 and 5.0 mg/L of toluene. The leopard frog (*Rana pipiens)* had a 9.5-d LC_{50} of 0.39 mg/L, while the salamander *Ambystoma gracile* had a 9.5-d LC_{50} of 0.85 mg/L. *Daphnia magna* had a 24hr-EC_{50} of 7.0 mg/L for immobilization.

The results from testing undertaken by B.C. Environment in partnership with the Canadian Petroleum Producers Institute in 1999 (static renewal tests) for *Daphnia magna* at a nominal hardness of 100 mg/L $CaCO_3$ are as follows:

Bioassay	mg/L
Daphnia magna, 21 d LC_{25}	15.0
Daphnia magna, 21 d LOEC	36.8
Daphnia magna, 21 d NOEC	8.7

The CCME classified the following as secondary. These secondary studies included two separate studies conducted independently and which had 48h-EC_{50}s for immobilization of this species (*Daphnia magna*) at 11.5 and 14.9 mg/L. Another secondary study had a 72h-EC_{50} of 12.5 mg/L for growth inhibition for the green algae *Selenastrum capricornutum.*

In marine water, sensitive species included the coho salmon (*Oncorhynchus kisutch)* that exhibited avoidance behaviour at 1.4 to 1.8 mg/L, pink salmon with a 24h- LC_{50} of 5.4 mg/L, and adult bay shrimp *(Crago franciscorum)* with a 96h- LC_{50} of 4.3 mg/L.

Species	Exposure Duration	Age/ Size	Response	Toxicity (mg/L)	Data Quality and Reference
Bay shrimp (*Crago franciscorum*)	Acute	Adult	**96h LC_{50}**	**4.3**	2°- Benville and Korn, 1977
Pink salmon (*Oncorhyncus gorbuscha*)	Acute	1-2g	24h LC_{50}	5.4	2°- Thomas and Rice, 1979
	Acute	Fry	**96h LC_{50}**	**6.52**	1°- Rice and Thomas, 1989
	Acute	Fry	48h LC_{50}	7.76	1°- Rice and Thomas, 1989
Sheepshead minnow (*Cyprinodon variegatus*)	Acute	Juvenile	96h LC_{50}	13	1°- Ward et al., 1981
Kelp shrimp (*Eualus suckley*)	Acute	1g	96h LC_{50}	19.8	1°- Rice and Thomas, 1989
Shore crab (*Hemegrapsus nudus*)	Chronic	--	8d LC_{50}	23.5-52.7	1°- Gharrett and Rice, 1987

RECOMMENDED GUIDELINES

THESE GUIDELINES are based on a review of the technical background information used to prepare the CCME Water Quality Guidelines for Toluene (July 1995 update), as well as recent information from the literature and other sources. The guidelines have been revised where appropriate to suit BC conditions, and are summarized in Table 1.

1. DRINKING WATER SUPPLY

An aesthetic objective of 0.024 mg/L for toluene in drinking water has been recommended by the Federal-Provincial Subcommittee on Drinking Water, Health Canada (1993) and is adopted for ambient conditions.

RATIONALE

This concentration yields no objectionable taste or smell, or no adverse health effects. Without treatment prior to entering a water distribution system, toluene concentrations will change little from ambient concentrations, especially when time from withdrawal to use is small. Therefore, the recommended concentration for water distribution systems will be the ambient water quality concentration for toluene.

2. FRESHWATER AQUATIC LIFE

The maximum concentration of toluene should not exceed the BC guideline of 0.039 mg/L. This guideline has been revised from the CCME guideline of 0.002 mg/L.

RATIONALE

We found that the data quality from the researchers was considered by CCME to be as satisfactory (ranked primary data) based on the requirements of the CCME Protocol. However, using the same Protocol, we have applied professional judgement since we have serious concerns about the results for the species used in guideline development by CCME.

The CCME guideline was established using the most sensitive species for an early life stage chronic test for rainbow trout (*Oncorhynchus mykiss*). The results are in a 1982-research paper from the University of Kentucky that is not widely available. This 27d LC_{50} was 0.02 mg/L, twenty times more sensitive than

reported by the same authors for leopard frog (*Rana pipiens*), or forty times more sensitive than the next most sensitive species that they reported, a salamander (*Ambystoma gracile*). In fact, the most sensitive species reported by independent researchers was for coho salmon (*Oncorhynchus kisutch*) with a 40-d weight decrease at 2.8 mg/L toluene, which is 140 times higher than the study used by CCME. All other authors report even higher concentrations for other species.

The difficulty in testing toluene due to its volatility can lead to problems in getting accurate toxicity measurements. For this reason, we believe that results from a flow-through test with constant replacement are the ideal. Unfortunately, the results in the literature do not always meet this ideal.

Since the rainbow trout (*Oncorhynchus mykiss*) study that reported the 27d LC50 of 0.02 mg/L was a flow-through test, we examined the acute to chronic ratios where available for the same species. We know on the basis of the CCME Protocol that the acute/chronic ratio should be about 2:1 for most species since the application factor recommended by CCME is 0.05 for acute data and 0.10 for chronic data. The actual ratios calculated from data in the literature were:

Species	Size	Test type	Toxicity Test	mg/L	Ratio	Primary Secondary	Information Source
Guppy	- 2-3 mos.	Static Static	96h-LC50 14d-LC50	28.2 68.3 (nom)	0.42:1	Primary Secondary	Galassi et al, 1988 Kuneman 1981
Fathead minnow	30-d 30-35d	FT FT	96h-LC50 8d-LC50	22 44.1	0.5:1	Primary Primary	Devlin et al, 1982 Hall et al, 1984
Chlorella vulgaris	- -	- -	3h EC50 10d EC50	207 245 (growth)	0.84:1	Secondary Secondary	Hutchison et al, 1980 Kauss and Hutchis 1975
Coho Salmon	0.3 gm fry fry	FT FT	96h-LC50 40d-wt dec.	5.46 3.9	1.4:1	Primary Primary	Moles 1981 Moles 1981
Goldfish	1-1.5 yr. 1-1.5 yr.	FT FT	96h-LC50 30d-LC50	22.8 14.6	1.56:1	Primary Primary	Brennimen et al. 1976 Brennimen et al. 1976
Daphnia magna	<24h <24h	Static -	24h-EC50 16d-LC50	7(immobilize) 3.75	1.87:1	Primary Secondary	Galassi et al, 1988 Hermens et al 1984
Fathead Minnows	Larvae Larvae Larvae larvae	FT FT FT FT	96h-LC50 7d-LC50 7d growth 7d-biomass	17.03 9.39 10.6 7.62	 1.81:1 1.61:1 2.23:1	Primary Primary Primary	Marchini et al 1992
Rainbow trout	- 4d-post hatch	Static FT	96h-LC50 27d-LC50	5.8 0.02	290:1	Primary Primary	Galassi et al, 1988 Black et al 1982

As can be seen, the ratio available for all species except the rainbow trout study are in the 2:1 range or less, while that for rainbow trout is more than 100 times greater than for any other species. This alone can be explained by either of two possibilities: the acute data used are too high or the chronic data from the study in question are too low. We tend to believe that the latter is the case, since rainbow trout and coho salmon are both salmonids, and although one would not expect identical results, one would expect that the toxicity would be similar. This is the case for the acute data (5.8 and 5.46 mg/L, respectively) but not for the chronic data, even though the acute tests were static (but primary data).

The chronic data themselves seem quite low in comparison to other work. The principle investigators have published toxicity data for other variables that we have questioned. These include data for copper which were reported as causing skeletal defects in the range from 1-5 ug/L but in the same paper, these researchers proposed a copper guideline at the 3-5 ug/L level. We find this interesting since the authors did not suggest that a guideline need to protect the most sensitive effect levels and that no safety factor was needed.

Although the research for the critical paper was reported in 1982, there have been no further studies reported in the literature on rainbow trout that yielded comparable results. This in itself seems strange. BC Environment, with the help of the Canadian Petroleum Producers Institute (CPPI), arranged for tests to be done through Environment Canada on early life stage rainbow trout (*Oncorhynchus mykiss)* and *Daphnia magna*. The tests unfortunately were not flow-through in nature, but static renewal tests and did not yield results for rainbow trout that we deemed to be helpful in establishing a guideline. (The results for testing *Daphnia magna* are presented earlier.)

We therefore question the validity of the rainbow trout chronic data. This is based on its low concentration relative to other work, the extremely high ratio produced in relation to acute studies (which seem to be of the right order-of-magnitude), and the fact that no other researchers have reproduced the results in the last twenty years. Of interest is the fact the US EPA has an alert level of 17.5 mg/L, while Quebec has a chronic guideline of 0.026 mg/L and an acute guideline of 0.58 mg/L.

In developing their guideline, the CCME applied a safety factor of 10:1. This was appropriate since toluene has high volatility, the guideline was based on a chronic study, toluene has low bioaccumulation potential and would not be expected to remain in the environment for prolonged periods of time (half-life is

up to two weeks in water). The LOEC/NOEC ratio for freshwater aquatic life (fathead minnow) is low (1.5:1).

We therefore used the next most sensitive species from the literature, the leopard frog leopard frog (*Rana pipiens)* which had a 9.5-d LC_{50} of 0.39 mg/L and applied the safety factor of 10:1 to produce a guideline of 0.039 mg/L. Although the research was performed by the same researchers as produced the data for rainbow trout, we do not have as much information available (e.g., no acute/chronic ratio) on which to refute these data (still approximately one order of magnitude lower than the next independent tests). We have no acute to chronic ratios, data from no other researchers on the leopard frog, or data for other similar species or data for other chemical compounds that might help us to validate the data. Therefore, we use the Ministry's *precautionary principle* in accepting these data at this time. By so doing, this yields a guideline of 0.039 mg/L that is about twice the level of concern raised for rainbow trout.

3. MARINE AND ESTUARINE LIFE

The maximum concentration of toluene should not exceed 0.33 mg/L. This guideline has been revised from the CCME guideline of 0.21 mg/L.

RATIONALE

The critical study used by the CCME to derive the guideline was classified as secondary data. In BC, we eliminated this study for determining the BC guideline, since the concentrations reported for the test were not measured but were estimated. The next lowest critical study with measured values had a 96h-LC_{50} of 6.52 mg/L for pink salmon (*Oncorhynchus gorbuscha*).

We maintained the safety factor used by CCME of 20:1 for BC based on not having a chronic study or a LOEC to NOEC ratio. Although toluene has a relatively short half-life and low potential to bioaccumulate, a safety factor of 0.05 was applied to the reference level for three reasons:

- the reference level was determined by acute rather than chronic toxicity testing,
- a LOEC to NOEC ratio was not available for conversion of the data, and
- there were few available studies on marine organisms.

4. CROP IRRIGATION

No water quality guideline for this use is recommended, as there are insufficient data on the adverse effects of toluene in irrigation water.

5. LIVESTOCK WATERING

Guidelines for livestock watering for BC are the same as for CCME, 0.024 mg/L.

APPLICATION OF GUIDELINES FOR AQUATIC LIFE

TOLUENE is a very volatile substance. The water quality guidelines recommended in this document are primarily based on controlled, laboratory bioassays that do not account for factors that may modify the toxicity of toluene in the field.

SETTING WATER QUALITY OBJECTIVES

Care must be exercised when the water quality guidelines are applied to assess environmental impacts of toluene, since there will be situations where toluene concentrations are continuously renewed (e.g., discharge from an industrial operation), or with the potential for only a minimal amount of volatilization (under ice cover). In these types of situations, a site-specific study should be undertaken and appropriate site-specific water quality objectives developed based on species present and actual toluene persistence and concentrations.

In many cases, water quality objectives will be the same as the guidelines. When concentrations of toluene in developed waterbodies are constantly maintained due to a continuous source or an environmental condition that prevents its degradation, then water quality objectives that are more stringent than the recommended guidelines may be justified. In some cases, socio-economic or other factors may justify objectives that are less stringent than the guidelines. Site-specific impact studies would be required in such cases.

Methods (e.g., water effects ratio, resident species toxicity in the field, etc.) are available to adapt the recommended guidelines to a given site by

considering these factors. Where necessary, these methods can be employed to set site-specific water quality objectives. Because these approaches are costly and time consuming, they are seldom used.

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